STOCKPILE RELIABILITY ASSESSMENT

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From its earliest days, Los Alamos National Laboratory (LANL) has had a prominent role in the development and evaluation of the nuclear weapons stockpile, but the end of the Cold War has brought significant changes to how this mission could be carried out. There have been significant reductions in the number of weapons, leading to a smaller, "enduring" stockpile. The United States is no longer manufacturing new-design weapons, and it is consolidating facilities across the nuclear weapons complex. In 1992, the United States declared a moratorium on underground nuclear testing; in 1995, the moratorium was extended, and President Clinton decided to pursue a "zero yield" Comprehensive Test Ban Treaty. However, the basic mission of LANL remains unchanged: LANL must evaluate the weapons in the aging nuclear stockpile and certify their safety, reliability, and performance even though the live test data that has traditionally been used for this evaluation can no longer be collected.

The collection of methods developed at LANL to address the evaluation of the stockpile in this new environment is called "Science-Based Stockpile Stewardship." From a statistical perspective, the work has been focused in two primary areas: how to develop models for these sorts of extremely complex systems that can capture the information from a variety of communities (for nuclear weapons, the communities include engineers, physicists, materials scientists, and policy makers), and how to combine information from extremely diverse sources (e.g., physics-based computer codes, subsystem test data, engineering judgment, historical data).

This talk will focus on the latter, and will illustrate methods that have been developed for the assessment of munitions stockpiles. As an example, consider the case where two data sets are collected about a particular unit. The first contains observations (Z, W), where Z is a pass/fail indicator from a test, and W is a vector of covariates, which may include such items as age, manufacturing lot, and storage conditions. The second contains observations (X, W), where X is a measurement of some property ("performance") of the unit. Since the measurement of both Z and X are destructive, there are no units where both Z and X are measured. The goal is to understand reliability as a function of the covariates, using information from both data sets.

To link the two data sets, we assume that the covariates W are related both to the performance measurement and to the pass/fail, but that they do not offer additional information about Z that is not already contained in X. A similar data structure also arises in medical applications where it is known as the errors-in-covariates with validation sample problem.

The first method developed to address the problem is a fully-parametric Bayesian model. The second is a semi-parametric model. For a known conditional distribution F of X given W, the maximum likelihood estimator solves the estimating equation

$$\sum_{i=1}^{n} \frac{\partial}{\partial \theta} \log p(Z_i|W_i, \theta) = 0.$$

When the conditional distribution of X given W is not known, Pepe and Reilley (1995) propose to use the validation sample to parametrically estimate the score function. We extend their ideas to estimate the score function using nonparametric regression techniques. Armed with such estimates, we then can estimate the parameter.

The main contribution is that, under suitable regularity conditions, this estimator $\hat{\theta}$ is asymptotically Gaussian with variance the inverse of the Fisher information for θ with known F, and we conclude that this estimator is fully efficient.

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